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NUMBER 114

MACHINE FORGING

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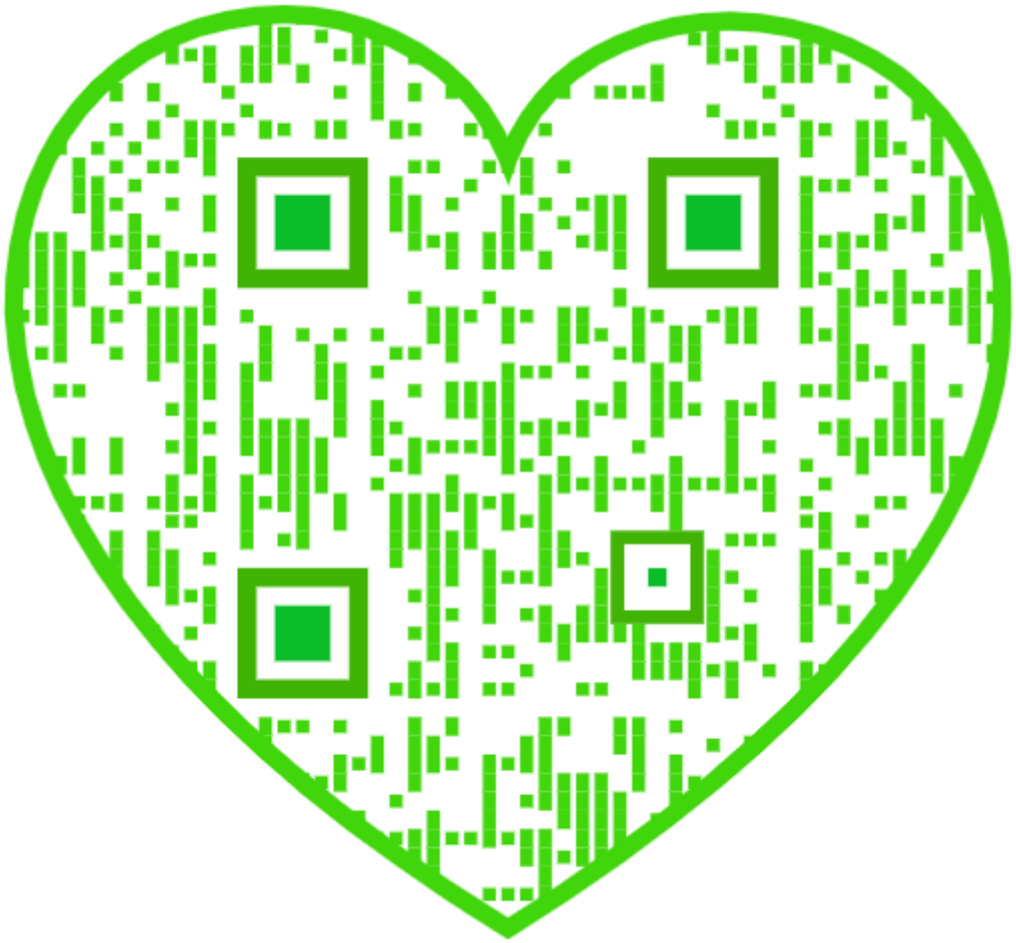

CHAPTER I

MACHINE FORGING DIES AND METHODS

Possibly the greatest advance made of late years in forging is the application of machine methods to the production of engine and machine parts. It is now possible to forge many parts from steel and wrought iron, which a few years ago could only be made from castings. This means a great saving of time and expense, as not only are machine forged parts much more rapidly made than those made from cast iron or steel castings, but they also cost considerably less to manufacture in large quantities. In the following, interesting examples of different types of upsets, bending and forming operations, etc., will be illustrated and described, together with a general description of the dies and tools used. This will give an idea of the remarkable possibilities of the upsetting and forging machine in its present-day development.

The Upsetting and Forging Machine

The upsetting and forging machine might be considered to a certain extent as a further development of the bolt and rivet making machine, which was originated almost a century ago; but forging machines are built much heavier than bolt and rivet machines and are designed especially to meet the demands in the production of difficult-shaped and heavy forgings. For the heavier types of machines, the base or main frame, as a rule, is made from one solid steel casting.

A typical upsetting and forging machine designed for heavy service is shown in Fig. 1. The bed of this machine is made from one solid casting of semi-steel. In order to provide against breakage caused by accidentally placing work between the dies, upsetting and forging machines are usually furnished with various safety devices to prevent serious damage to the machine. The safety device in this machine consists of a toggle-joint mechanism for operating the movable gripping-die slide. The gripping die slide *A*, Fig. 1, is operated by two cams *B* and *C* on the main crankshaft *D*. Cam *B* serves to close the dies which grip the work; cam *C* operates the opening mechanism for the dies. These cams are in contact with chilled cast-iron rolls *E* and *F* carried in the toggle slide *G*. The automatic grip relief is controlled by the by-pass toggle *H* and heavy coil spring *I*. This toggle does not come into play until the strain is such that it would cause damage to the working mechanism of the machine, or in other words until the maximum power required to hold the movable die from sp
is attained. The relief resets automatically on the b
machine, thus making a second blow possible with
Some idea of the gripping pressure exerted b

anism operates is indicated in Fig. 2. This piece, which has been flattened between the opposing faces of the gripping dies, is a 2-inch round bar of 0.10 to 0.15 per cent carbon steel, 9⅝ inches long. The flattened portion is 3⅝ inches wide by 5 inches long and 23/32 inch thick. The piece, of course, was heated to a forging temperature before

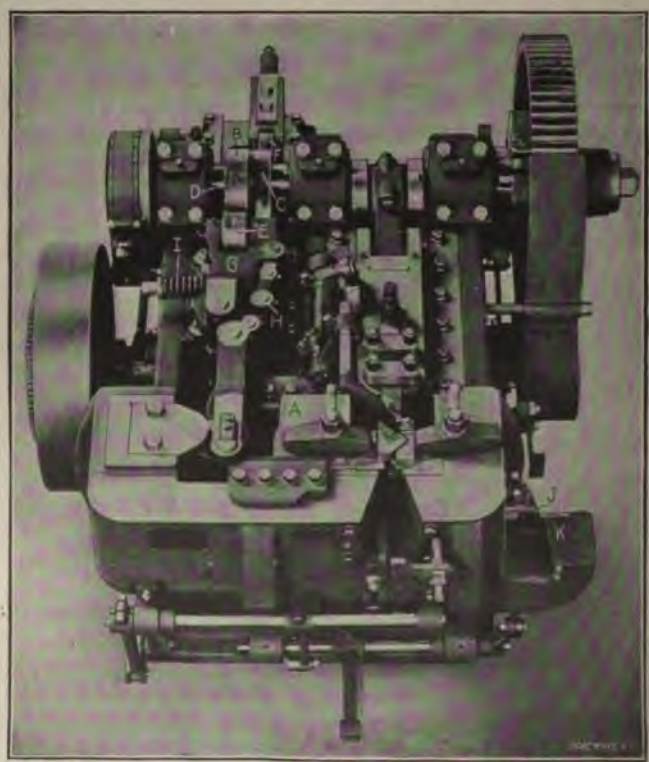

Fig. 1. "National" Upsetting and Forging Machine having a Safety Relief Mechanism for operating the Gripping Dies

being placed between the opposing faces of the dies and was flattened to the condition shown in one squeeze. This illustrates a feature peculiar to this type of machine in that it can be used for squeezing or swaging operations, these being carried on between the opposing faces of the gripping dies. In many cases this allows work to be handled that is generally formed or flattened by the side shear *J*, which is operated from the movable die slide, being a continued arm of the same casting. As a rule, the side shear is used for cutting off stock, and is also sometimes used for bending operations, suitable dies or cutting tools for this purpose being held in the movable slide *J* and stationary bracket *K*.

Another type of upsetting and forging machine in which the working mechanism of the machine is protected from serious injury in a differ

ent manner, is shown in Fig. 3. In this machine the safety device consists of a bolt *A* connecting the die slide *B* and the slide *C* operating it. When any foreign body intercepts the gripping dies, the bolt *A* is sheared off, thus providing for a positive grip and at the same time furnishing a safety device that protects the working mechanism of the machine against serious injury.

Fig. 2. Extent to which a Bar is flattened between Gripping Dies of "National" Forging Machine before Relief operates

A good example of an upset forging operation which can be handled successfully in an upsetting and forging machine, is the castellated nut shown at *A* in Fig. 4. This type of nut is produced practically without waste of stock in from two to three blows. The gripping dies and tools used are shown in Fig. 4, and also in detail in Fig. 5, where the construction of the tools can be more clearly seen. Referring to the latter illustration, it will be noticed that the dies *C* and *D* are made in two pieces. This is done

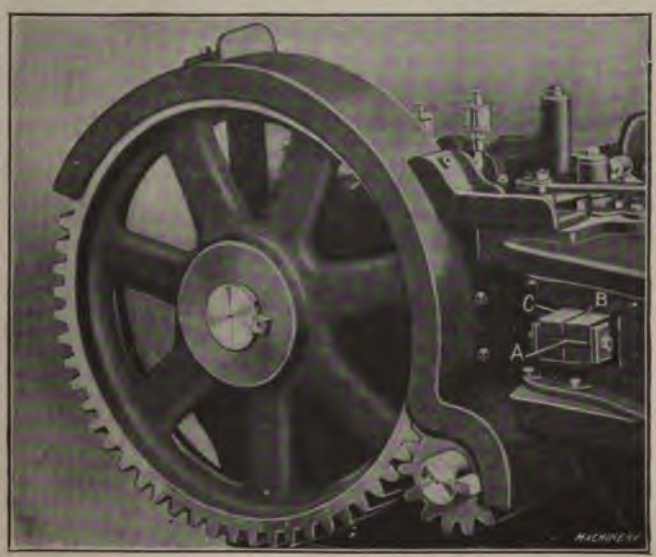

Fig. 3. Ajax Upsetting and Forging Machine showing Safety or Shear Bolt, providing a Safety Relief for the Gripping Dies

in order to facilitate the machining operations, and in many cases it enables the dies to be made much cheaper because of the simplicity in construction. These dies are made from scrap driving-

axle steel which contains about 0.60 per cent carbon, and are hardened in the usual manner, the temper being drawn to a light straw color.

The plunger *E* which upsets the end of the bar into the lower impression in the dies, is made in three parts; this facilitates its construction and the method of manufacture. The body is made from a piece of soft machine steel, on the front end of which a hardened bushing *F* is held by a pin. The inside of this bushing is of a hexagon shape to form the sides of the nut. Screwed into the body of the punch is a former *G* which is machined to such shape that six "wings," as shown, are formed around its periphery, these producing the castellated grooves in the head of the nut. The former *G* is pointed, and rough-forms the hole in the nut. The top punch which is used for completely punching the hole in the nut and at the same time severing it from the bar is also made from a machine steel body *H* into which is screwed a hardened steel punch *I*, this being prevented from loosening by a pin driven through it.

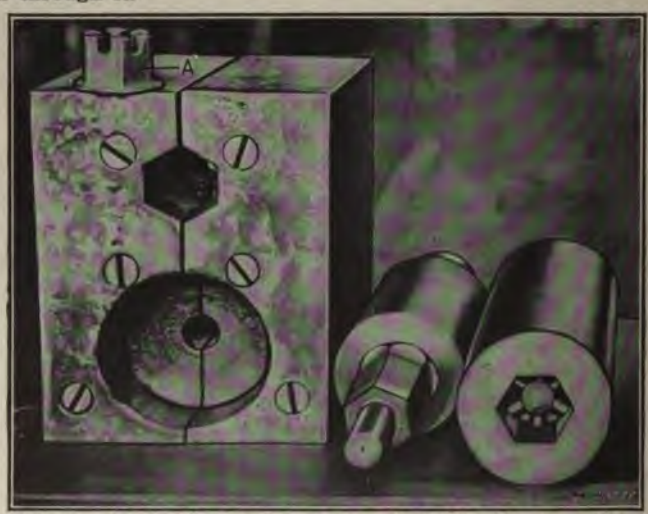

Fig. 4. Dies and Tools used in making a Castellated Nut in an Ajax Forging Machine in the L. S. & M. S. Railway Shops at Collinwood, Ohio

The method of producing a hexagon castellated nut in a forging machine is as follows: A bar of the required size (which must not exceed the root diameter of the thread in the finished nut) is heated in the furnace to a temperature of from 1400 to 1600 degrees F., depending upon the material, and is then brought to the forging machine and placed in the lower impression of the gripping dies. Then as the machine is operated, the lower plunger advances, upsetting the end of the bar and forming the excess metal into a nut of the required shape. The bar is now quickly removed from the lower impression, placed in the upper impression, and the machine again operated; whereupon the top plunger advances, completing the hole in the nut and attaching the metal thus removed to the end of the bar. These two operations are

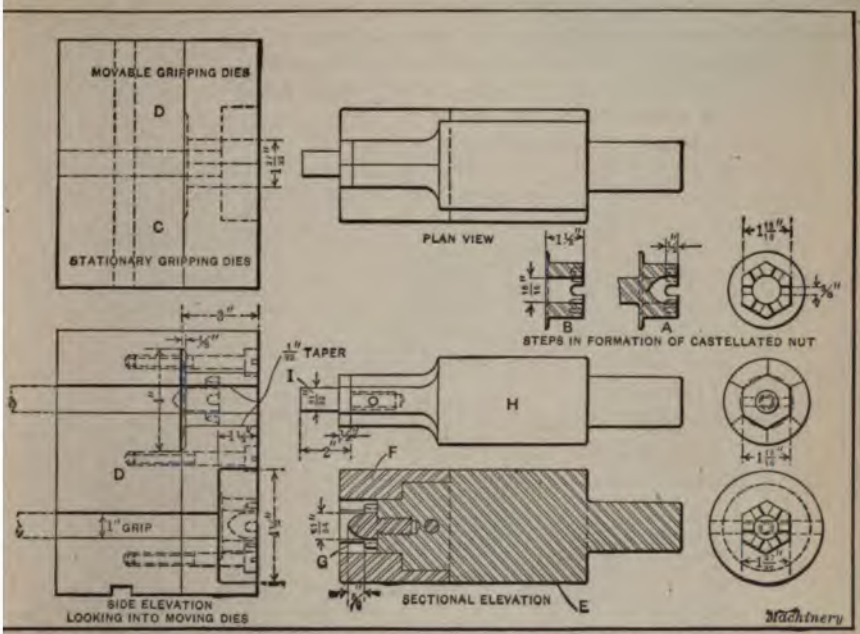

Fig. 5. Details of the Dies and Tools used for making the Castellated Nut shown in Fig. 4

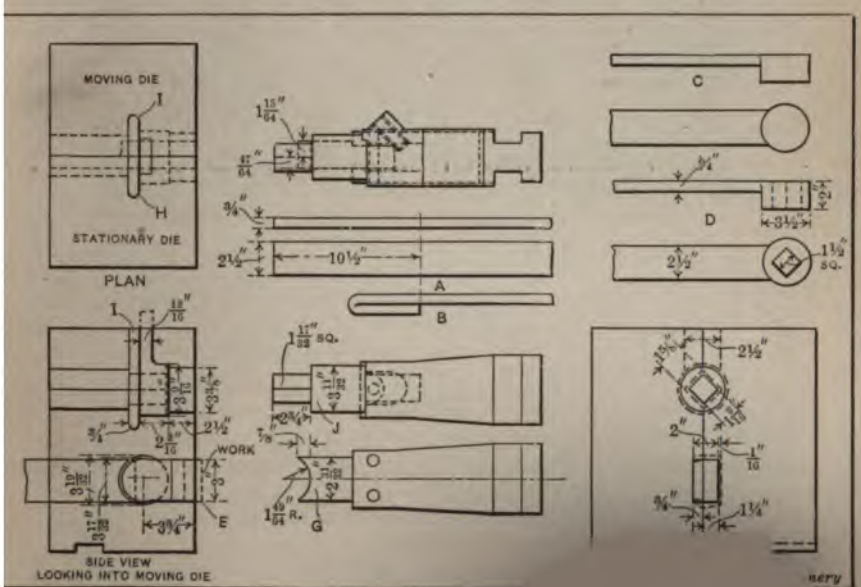

Fig. 6. Dies and Tools used in making a Lo

indicated at *A* and *B* in the illustration. This interesting method of making castellated nuts is used in the Collinwood shops of the L. S. & M. S. Railway. The only material wasted in the production of a castellated nut of this character is the slight excess of stock formed into a fin, which must be removed, of course, in a subsequent operation.

Another interesting example of castellated nut forging in which the excess metal is used in the formation of a washer on the nut and thus eliminates all waste of material, is shown in Fig. 7. The construction of the tools here

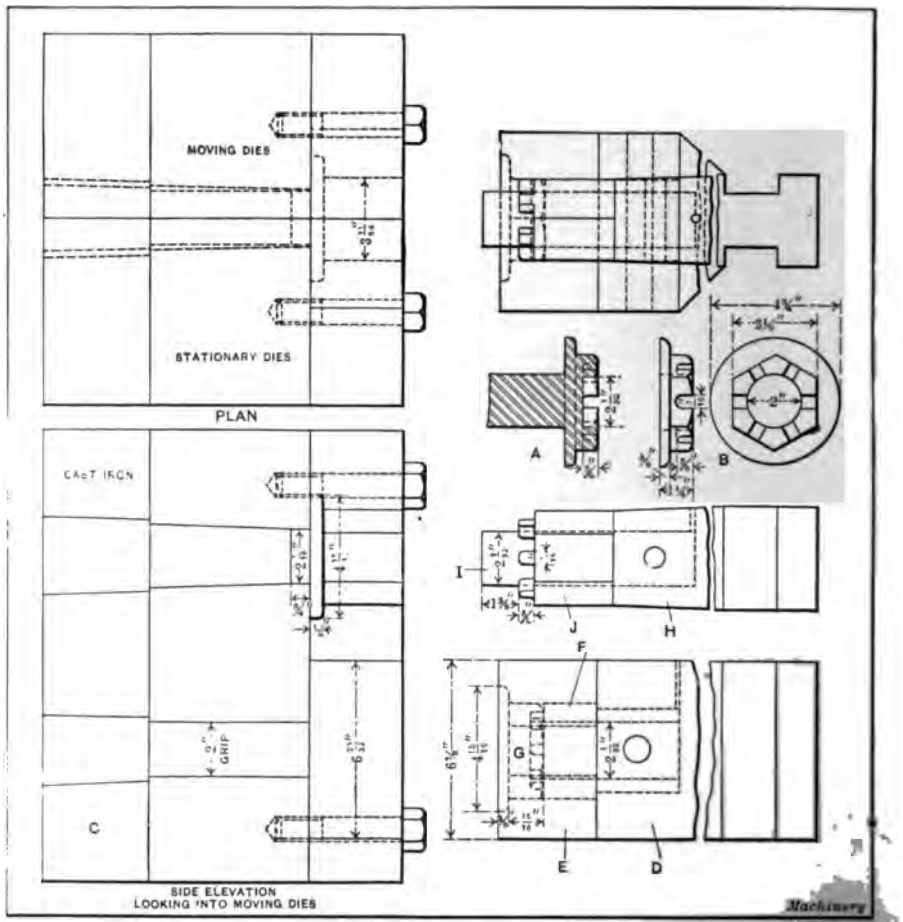

Fig. 7. Dies and Tools used for making a Combination Washer and Castellated Nut which is produced without any Waste of Stock

illustrated is almost identical with that shown in Figs. 4 and 5 wit ception of the punches and also the utilization of a cast-iron bl partly completing the construction of the gripping dies. The part ping dies which is made from cast iron is not used as a gripping s

hence does not need to be made from steel to provide for wear. The lower punch *D* is in this case made from machine steel and is provided with a tool-steel head *E* which is bored out and formed to a hexagon shape. Inserted in this is a sleeve *F* for forming the castellated portion of the nut. A punch *G* rough-forms the hole in the nut. The upper plunger *H* carries a punch *I* which completely forms the hole in the

Fig. 8. Dies and Tools used in making an Enormous Upset in a 6-inch Ajax Universal Forging Machine

nut by punching the bar back, and by means of the castellated washer *J* finish-forms the castellated grooves in the nut. The steps followed in the production of this combination castellated nut and washer are shown at *A* and *B* in the illustration. A 2-inch bar of wrought iron is used, and it requires a length of 4 inches to form the nut and washer.

Dies and Tools Used for Making a Locomotive Trailer Pin

The locomotive trailer pin shown at *A* in Fig. 8 represents about the maximum amount of upset which can be satisfactorily made in a forging machine, and in fact, is much greater than that usually recommended. This example which is supposed to be the largest upset ever made by machine methods was accomplished in the Chicago shops of the C. & N. W. Railway, on a 6-inch Ajax universal forging machine. This trailer pin [illegible] from a 3-inch round wrought-iron bar, 26

inches long, and an excess amount of stock equal to 10¾ inches in length is put into the upset in one blow. The dimensions of the upset square flange are 7⅞ inches across the flats and 10 5/16 inches across the corners, by 1⅜ inch thick. The circular flange is 5⅞ inches in diameter by ⅝ inch long. After the work is given the first blow with the plunger *B*, it is reheated and the work is again placed between the gripping dies *C*, only one of which is shown. The machine is again operated and the part given another blow which serves to close up the

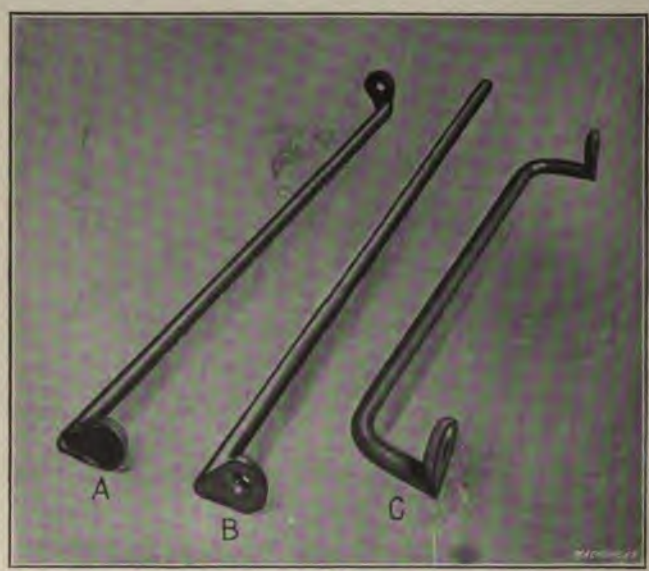

Fig. 9. Three Steps in the Formation of Ladder Treads for Freight Cars, accomplished in a "National" Forging Machine

texture of the steel and eliminates the defects caused by the structure of the steel pulling apart during the upsetting operation. This large upset gives an idea of some of the possibilities of machine forging in making engine parts, etc.

Bending and Forming Operations

The making of ladder treads for freight cars is a good example of bending and forming operations that can be handled successfully in the upsetting and forging machine. Fig. 9 shows three of the steps in the production of a ladder tread which is completed to the shape shown at *C* in five operations.

The dies and tools used for forming the feet of the ladder tread are illustrated in Fig. 10. The first operation is indicated at *A* and consists in cutting off a bar of ⅝-inch iron to the required length. This is heated on one end, placed in the lower impression in the gripping dies *G* and *H* and given a blow by the plunger *I* which forms the end of the rod into the shape shown at *B*. In this operation, the stock is

upset just far enough so that it will not buckle in front of the dies.

The second operation bends and forms the stock back into a solid forging as indicated at *C*, this being accomplished in the second impression in the gripping dies by plunger *J*. The final forging operation, the result of which is shown at *D*, completes the foot, the upper impressions in the dies being used for this purpose; these are made the exact shape of the foot, and the plunger *K* has a pin in it which punches the hole in the foot to within 1/16 inch of passing through the 9/16-inch stock. The final operations which are performed in a bulldozer or other bending machine consist in bending both ends of the tread to the required shape. This requires two operations, which are indicated

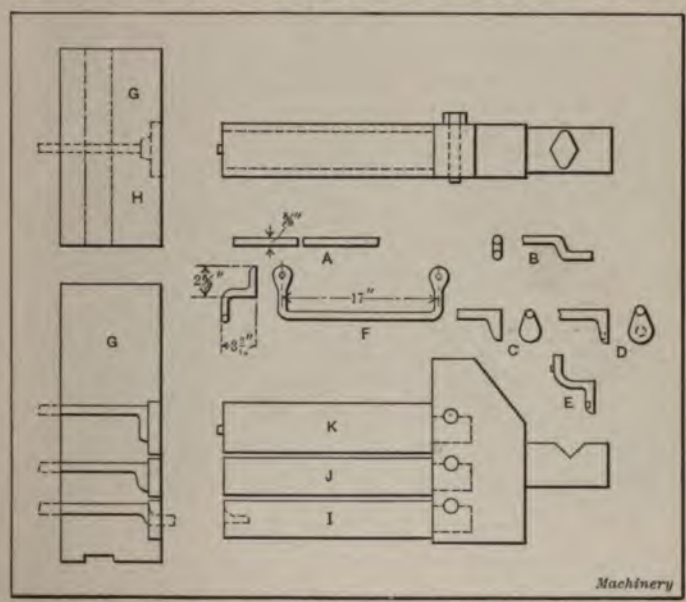

Fig. 10. Dies and Tools used in forming the Feet of Ladder Treads

at *E* and *F*, respectively. Before the final bending, the forging is taken to an emery wheel to remove the burrs formed when forging the feet.

The eye-bolt shown in two stages of its formation, at *A* and *B* in Fig. 11, is another example of a bending and forming operation accomplished in a forging machine. This eye-bolt is made from a 1⅜-inch round wrought-iron bar, and is completed in two blows in a 3-inch Ajax forging machine, using the dies and tools illustrated. The construction of the gripping dies is rather unusual and interesting. The lower impression in the dies consists of two movable members *C* which slide on four rods *D* and are provided with tongues *E* which fit in corresponding grooves in the movable and stationary gripping dies. The pins, of course, act as [illegible]ding these sliding members *C* in the gripping dies. [illegible]ut against the adjustable lock-nuts *F* by

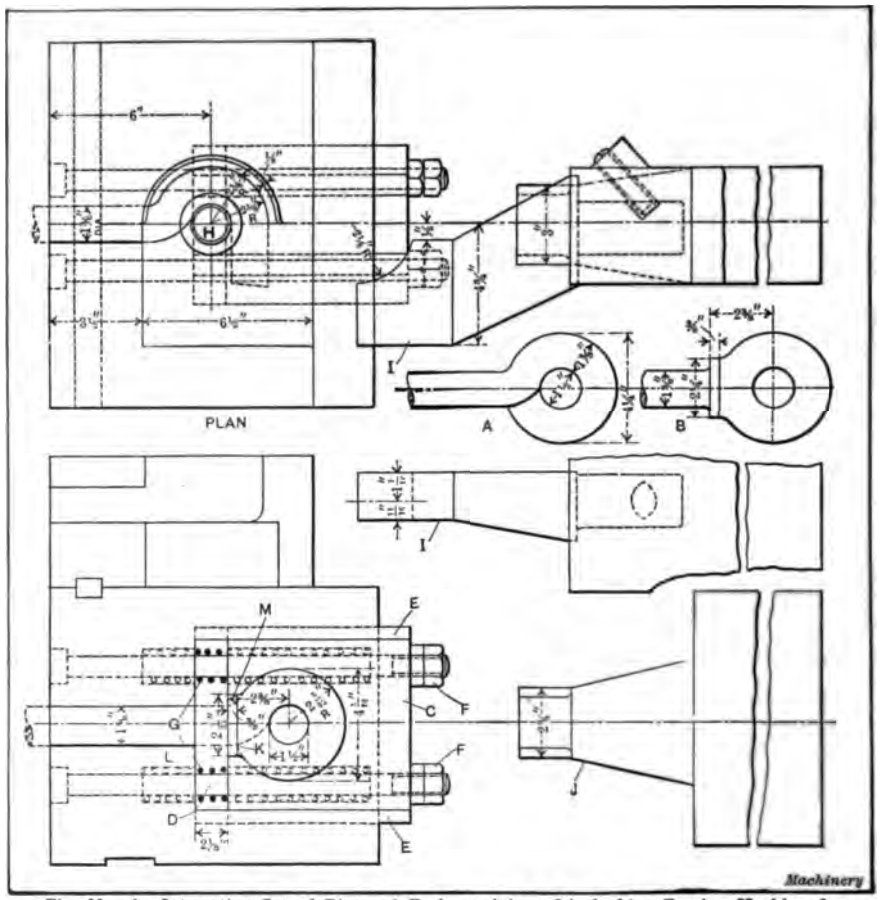

Fig. 11. An Interesting Set of Dies and Tools used in a 3-inch Ajax Forging Machine for forming Eye-bolts in Two Blows

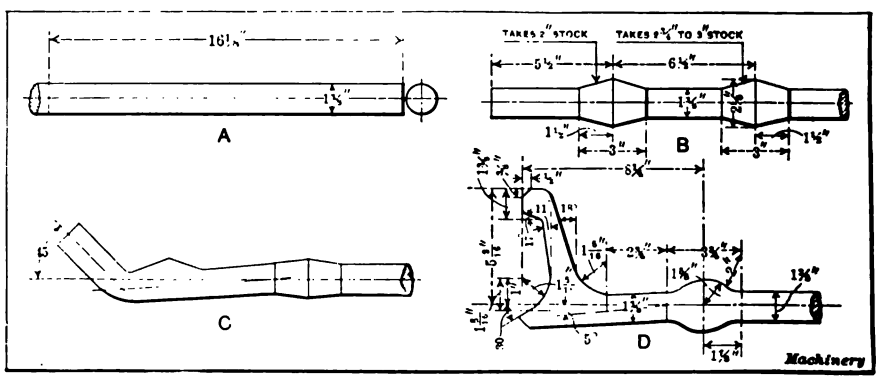

Fig. 12. Sequence of Operations on Ford Front Axle accomplished in "National" 3½-inch Forging Machine

The method of operation is as follows: The stock is first heated for a portion of its length to the correct temperature, then placed in the upper impression of the stationary die, being located in the correct endwise position by the stop of the machine. The machine is then operated and when the movable die closes on the work, it grips it and at the same time forces the heated end of the stock around pin *H* held in the stationary die. Just as soon as the dies close tightly on the work, punch *I* comes in contact with the bent end of the bar and forms it around the pin *H*, bending the work into the shape shown at *A*. The dies now open and the work is removed and placed on the pin forming the center portion of the impression in the blocks *C*. The

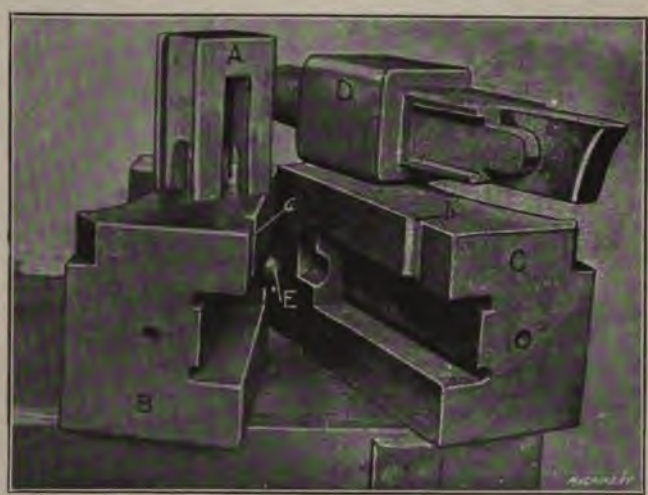

Fig. 13. Dies and Tools used for forming a Driver Brake Adjusting Rod Block in a 5-inch Ajax Forging Machine

machine is again operated and as the dies close, the ram *J* advances and forces the blocks *C* forward, carrying the "eye-end" of the work along with it.

Now as both parts of the bar—"eye-end" and body—are rigidly held in the gripping dies and movable blocks *C*, it is evident that the part of the bar at point *K* must be upset. The result of this displacement of the stock causes the formation of a shoulder on the bar at the base of the eye, formed by the circular impression *M* in the blocks *C*. The amount of stock required to form the boss at the base of the "eye" is governed by the position of the locknuts *F*. The ram *J* and gripping dies are made from steel castings. The four compression springs *G* are 10¾ inches long when extended, of ¼ inch pitch; 5/32-inch diameter wire is used, and the outside diameter of the spring is 1 3/16 inch.

Dies and Tools for Forming a Driver Brake Adjusting Rod Block

A difficult forming operation accomplished in the forging machine is shown in Fig. 13. The part *A* is a driver brake adjusting rod bloc[k-]

used on freight cars. It is made of wrought iron and is completed in two blows in a 5-inch Ajax forging machine. The method of procedure in making this piece is to first cut a piece of rectangular bar iron to the required length and then bend it into a U-shape in the bulldozer.

Fig. 14. A Heap of Finished Forged Coupler Pocket Filling Blocks

Fig. 15. 5-inch Ajax Forging Machine at Work in the Collinwood Shops of the L. S. & M. S. Railway, set up for making Coupler Pocket Filling Blocks for Freight Cars

It is then taken to the furnace where it is heated to the proper temperature, and a "porter" bar, about ¾ inch in diameter, is also heated. This is joined to the bent piece (which is to form the block) and the latter is placed between the gripping dies, the bar being used simply

as a means of handling. The dies shown at *B* and *C* are provided with half-round impressions shown at *a* and *b* through which the "porter" bar projects. As the machine is operated, the front end of plunger *D* cuts off the "porter" bar and forces the bent piece into the impressions in the gripping dies. While the piece is still held in the dies, the machine is again operated and the work given a second blow, this, of course, all being done in the one heat. The round-ended plug *E* at the end of the impression in the stationary die forms an impression in the end of the block and serves as a spot for a subsequent drilling operation. Work of this character demands a forging machine in which a rigid gripping mechanism is provided, if excessive fins on the work are to be avoided. The reason for this is that the plunger, in forcing the metal into the dies, has a tendency to separate them.

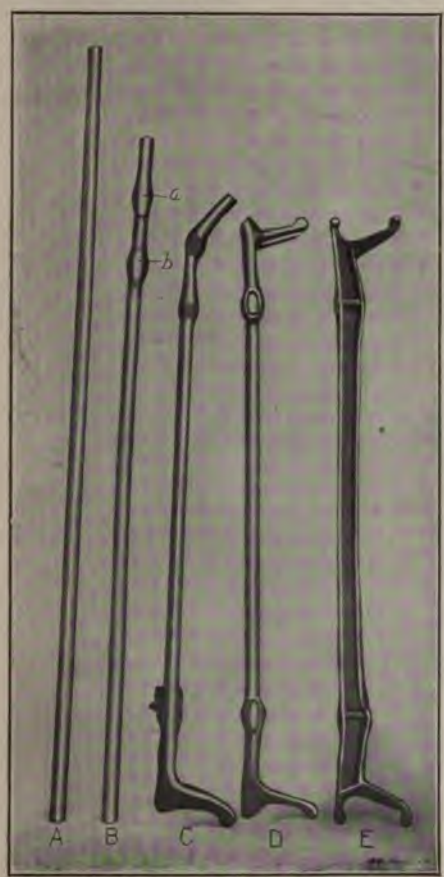

Fig. 16. Sequence of Forging Operations on the Ford Front Axle

Fig. 14 shows a forging made in practically the same manner as that illustrated in Fig. 13. This part, a coupler pocket filling block, is used on freight cars, and is made from scrap arch bars cut up into pieces of the desired length. These pieces are first formed into a U-shape in a bulldozer and are then brought to the furnace shown to the right in Fig. 15. Here they are heated to the desired temperature, then gripped with the tongs and placed on the shelf of the back stop *A*. The forging machine operator then lifts the piece from the shelf by means of a "porter" bar, and places it between the gripping dies, where the forging is given two blows and then thrown down in the sand to cool off. Fig. 14 gives some idea of how this coupler pocket filling block is produced. The piece of arch bar which has been formed to a U-shape in the bulldozer still forms the end of the block, the sides or webs being formed by bending in the arch

and lapping up the open ends. This can easily be seen by referring to the piece *A* in the illustration, where the joint formed in this manner is clearly shown. The burrs formed on these pieces are removed in a subsequent operation.

Forging an Automobile Front Axle

The making of the Ford automobile front axle by forging machine methods is an excellent example of the general adaptability of the upsetting and forging machine to the manufacture of miscellaneous parts from carbon and alloy steels. When used in conjunction with a steam hammer or bulldozer, there is practically no limit to the range of work which can be successfully handled. One of the most recent

Fig. 17. "National" 3½-inch Forging Machine used in accomplishing the Preliminary Operations on the Ford Front Axle

developments in forging-machine methods which should be of unusual interest to many manufacturers is the application of forging machines to the welding of machine and engine parts. This in many cases permits the utilization of scrap metal, thus converting practically valueless material into expensive machine parts. Some interesting forging operations employed in the production of the Ford front axle and other parts, will be described in the following:

In Fig. 16 is shown a series of interesting operations performed in the 3½-inch "National" forging machine shown in Fig. 17, the work being the front axle for the Ford automobile. This front axle is made from a vanadium steel bar 1⅝ inch in diameter by 67¾ inches long, as shown at *A* in Fig. 16. The first forging operation consists in form-

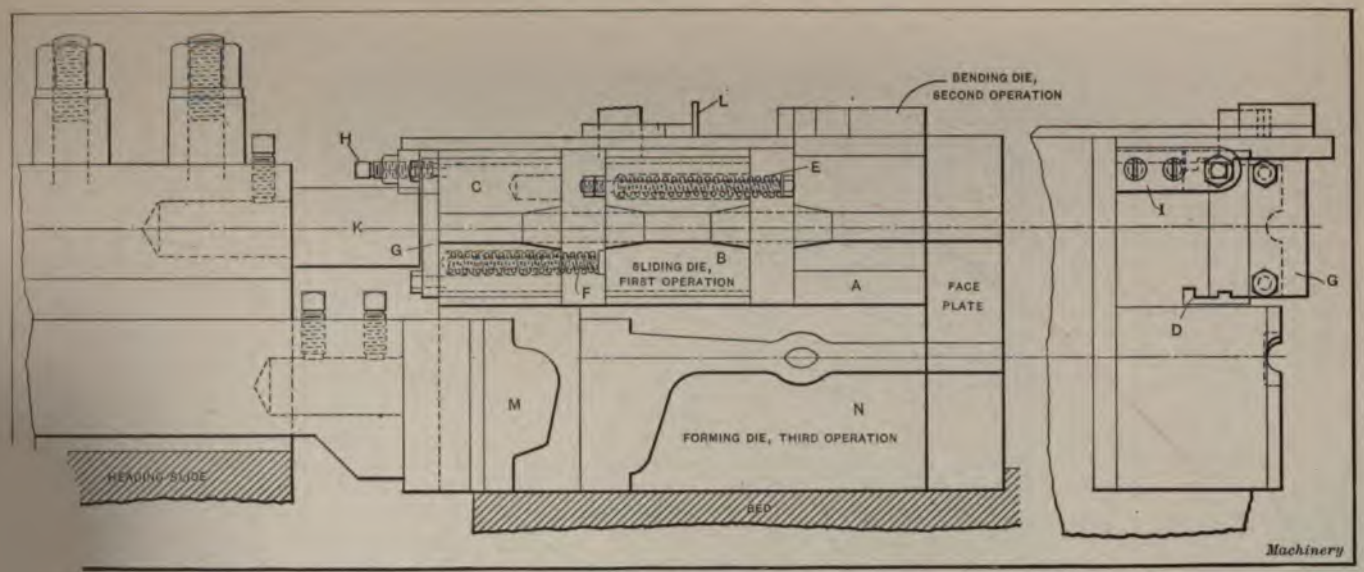

Fig. 18. Construction of Dies and Tools used in the "National" Forging Machine for making Ford Front Axle

two bulges *a* and *b*. Both ends of the bar are formed s manner, but in separate heats. This operation, n is also indicated at *B* in Fig. 12, shortens the ends of the bar from a length of 16⅛ inches to 13½ inches, which means that 2⅝ inches of stock is put into the bulges. The forging machine dies for performing this operation are shown in Fig. 18, the bulging being accomplished in the top members. In order to form both bulges at once it is necessary to have the top members of these dies constructed in such a manner that the blocks carrying the impressions are free to slide forward when acted upon by the plunger held in the ram of the machine.

As will be seen by referring to this illustration, one-half of the larger bulge is carried in block *A*, while the other half of the impression is carried in the sliding block *B*. In the opposite end of the sliding block *B* is provided one-half the impression for the smaller bulge, the other half being formed in the sliding block *C*. These sliding blocks *B* and *C* are held by tongue plates *D* to the main body of the top forging die in which they are free to slide. They are held in their outward positions by coil springs *E* and *F*. Coil spring *E* is carried on a stud held in sliding block *B*, while coil spring *F* is carried on a stud screwed into block *B* and fitting in a clearance hole in sliding block *C*. The stock, when heated to the correct temperature, is located in the proper posi-

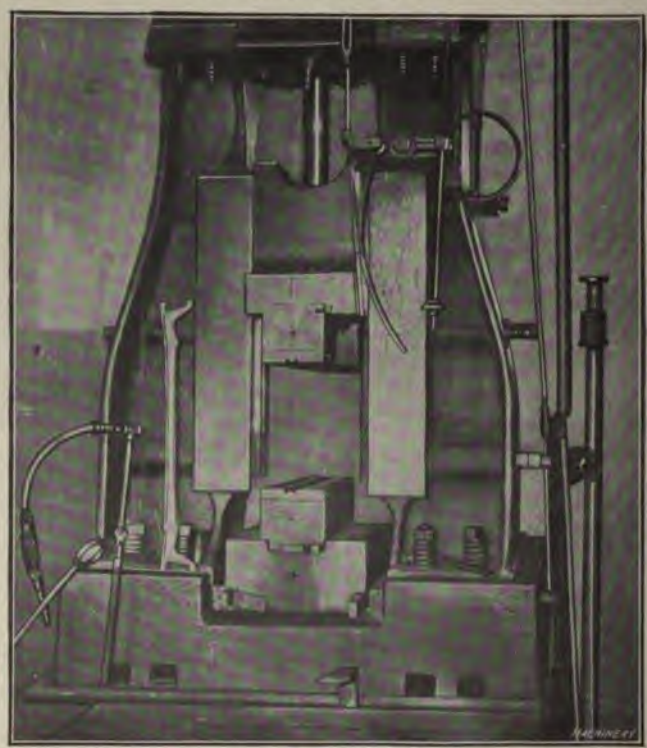

Fig. 19. "Massillon" Steam Hammer used for bringing the Ford Front Axle to Final Shape

tion in the dies by block *G*, which is fastened by cap-screws to block *C*, and covers the hole in the dies as indicated in the end view. Block *C* is located in its proper "out" position by means of adjusting screw *H*, held in block *I*, fastened to the top member of the forging die.

The stock which has been heated for a distance of about 18 or 20 inches is placed in the impressions in the upper members of the stationary gripping dies. The machine is then operated; the gripping dies hold the work rigidly, while plunger *K* advances and forces sliding

block *C* forward until it is in contact with block *B*. The forward movement of the ram continues until block *B* is forced up against block *A*, when the ram recedes, the dies open, and the forging is removed. It is evident that as the work is held rigidly between the opposing faces of the gripping dies, the advance of these sliding members can only accomplish one result, which is to upset the excess metal and expand it into the impressions provided in the dies, thus forming the bulges.

The next operation on the front axle, which is indicated on the top of the axle at *C* in Fig. 16, and also at *C* in Fig. 12, consists in bending

Fig. 20. Upper and Lower Dies used in Steam Hammer shown in Fig. 19 for finish-forming the Ford Front Axle

the end around in order to locate the material in the required position for forming the knuckles of the axle. This operation is handled in the dies shown in Fig. 18, that member which accomplishes the work being formed on the top face of the top members of the dies. The bar, which is still in its initial heat, is laid on top of the dies and in contact with the stop gage *L*. The machine is then operated, and as the dies close, the impressions formed on the projection of the top die twist the end of the bar around and form it to the desired shape.

The bar is now placed in the furnace and again heated to the proper

temperature. Then it is brought to the forging machine and placed in the lower impression in the gripping die shown in Fig. 18. The forging machine is then operated, and as plunger *M* advances, it upsets and forces the work into the impressions in the lower gripping dies *N*, forming the front axle to the shape shown at *D* in Figs. 12 and 16. This completes the operations on the front axle which are handled in the forging machine. After one end of the bar has been formed to the desired shape, the other end of the bar is heated and passed through the same operations. Before the front axles are passed on to the final drop-forging operations, the burrs and fins formed in the forging machine dies are removed.

The final forming of the front axles is done under a steam hammer of the type shown in Fig. 19, the dies illustrated in Fig. 20 being used. Only one end is completed at a time; this will be seen by referring to the dies shown in Fig. 20. The axle is heated for a little over one-half its length and is placed on the lower die in the steam hammer. The operator is careful to locate the end of the bar so that the stock to form the knuckles is in the proper position in relation to the impression in the die before the first blow is struck; then ten successive blows are struck and the axle is removed and taken to a punch press holding a shearing die which removes the fins. The axle is then brought back to the steam hammer, given a final blow and laid down to cool off in the sand.

After one end of a batch of front axles has been finished in this manner, the other end is heated and carried through the operations described. The axles are then again taken to the furnaces, heated and placed in a fixture held in a punch press. where they are stretched to the exact length—52½ inches.

CHAPTER II

WELDING IN THE FORGING MACHINE

There are three methods in general use for welding or joining pieces together in a forging machine. The selection of the one to employ depends largely on the shape of the work and other requirements. The most common method in general use is lap-welding, of which there are several applications. The next method in importance is pin-welding. Butt-welding is as a rule used only where it is impracticable to handle the work in any other way.

In regard to the materials that can be handled, wrought iron can be very readily welded in the forging machine, and when proper care is taken this can be successfully done without resorting to the use of fluxes except in unusual cases. Machine steel does not weld as readily as wrought iron, and usually it is advisable to use a welding compound on the faces of the parts it is intended to join. The following ingredients make a satisfactory flux for steel welds: To one part of sal-ammoniac add twelve parts of crushed borax. Heat slowly in an iron pot until the mixture starts to boil, then remove and reduce to a powder. Then apply the powder to the welding faces of the work shortly before removing it from the furnace, putting the work back in the furnace for a short period after applying the flux. Alloy steels, while they can be worked successfully in a forging machine, cannot be successfully welded. As a rule, parts made from alloy steels can only be worked into shape by upsetting and forming.

Lap-welding and Forming Operations

A simple example of lap-welding in conjunction with a forming operation is shown in Fig. 21, where the various steps in the making of a draw-bar hanger are illustrated at *A*, *B* and *C*. The first operation consists in cutting a 2¼ by ¾-inch bar of wrought iron to a length of 19¾ inches—this allowing a sufficient amount of excess material to form the two bosses, one on each end. The bar is then heated in the furnace and placed in the side shear of the machine as shown at *D*. The forging machine is now operated and the tools held on the side shear arrangement partly cut off the bar and bend the nicked end around about one-quarter turn. It is then removed from the machine, placed on an anvil, and the bent end lapped over as shown at *B*, after which it is again put in the furnace and heated to the proper temperature; it is then removed and placed in the lower impressions in the gripping dies, being properly located for length by the back stop *E*. The machine is then operated, completing the weld and forming the upset square boss on one end of the bar in one blow. After performing the operations described on all of the bars, the other end is handled in practically the same manner, using the upper impressions in the gripping dies and subjecting the bar to three heats instead of tw

Dies and Tools for Making Locomotive Ash-Pan Handle

Fig. 6 shows a locomotive ash-pan handle that is produced in a similar manner to the draw-bar hanger shown in Fig. 21, the operations on this piece being indicated at *A*, *B*, *C* and *D*, respectively. The first operation is to cut off a bar *A* of the required length, as before mentioned, and bend one end over into the shape at *B*, putting it into the required condition for welding, forming and piercing in the forging machine. The welding and forming operations which are indicated at *C* are handled in the lower impression of the dies shown to the left of the illustration, the position of the work before forming being indicated by the dotted lines *E*. The lower impression is formed as shown in the end view of the dies at *F*, being provided with a draft in the impression of 1/16 inch on the diameter in order to facilitate the "flow" of the metal and the removal of the forging from the dies. The punch *G* is made with a concave end which forms a portion of the

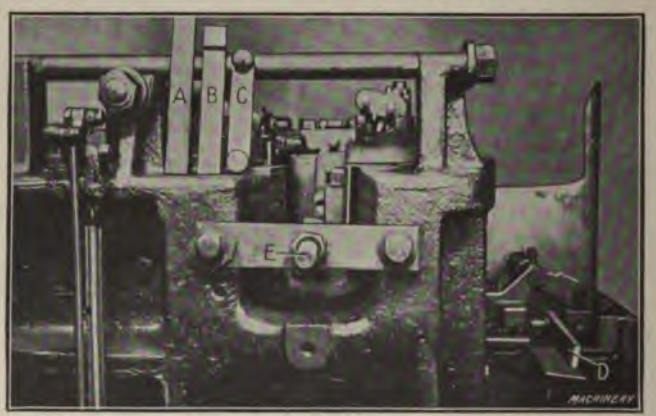

Fig. 21. Making Draw-bar Hangers in a 3-inch Ajax Forging Machine

boss and upsets the material into the desired shape at the same time.

After being welded and formed, the work is removed from the lower impressions and placed in a vertical position in the upper impressions in the dies. Here the square hole, as indicated at *D*, is punched. As the gripping dies are made from steel castings, they would not stand up satisfactorily for a piercing operation, so in order to punch a clean hole two steel plates *H* and *I* are inserted in the movable and stationary members of the dies. These are so shaped that a square hole is formed when the dies come together. The hole is pierced by the punch *J*, the construction of which is clearly shown in the illustration. Both punches *G* and *J* are made from steel forgings and hardened.

Dies and Tools for Making Car Float Stanchion Foot

Another interesting example of lap-welding which is used for the purpose of enlarging a 2-inch bar to 6 inches in diameter to form the head on a car float stanchion foot is illustrated in Fig. 22. This car part, as indicated at *A* and *B*, is made from a wrought-iron bar 2 inches

in diameter, to which a rectangular block *A*, 6 by 3½ by ¾ inch, is welded. Block *A* is first cut to the required length, and bent into a U-shape in the bulldozer. Then it is placed on the round bar as indicated at *B*, and the two parts are put in the furnace, where they are heated to a welding temperature. The parts are now quickly removed, given a tap to stick them together, placed in the forging machine, and with one blow are formed to the shape shown at *C*. The dies and tools used for this operation, which are also shown in the illustration, are of simple construction, consisting only of two gripping dies and one plunger.

Dies and Tools for Making Locomotive Spring Bands

A lap-welding operation which is handled in a different manner from those previously described is shown in Fig. 23. This piece, which is a

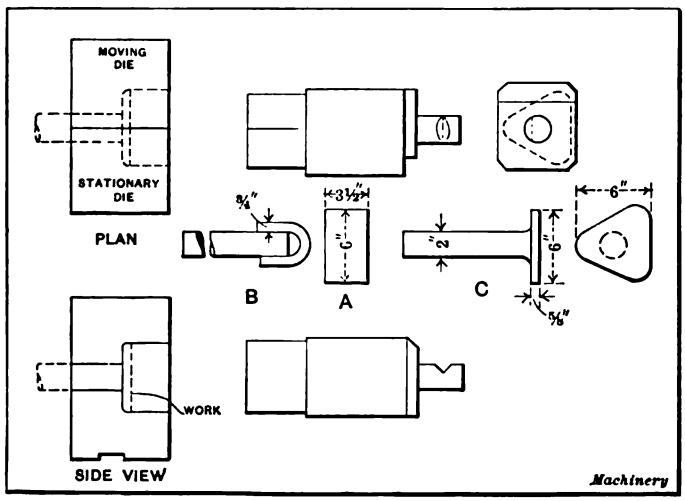

Fig. 22. Forging Machine Dies and Tools for making a Car Float Stanchion Foot

spring band for a steam locomotive, is made from a rectangular wrought-iron bar 2¼ by ⅜ by 19 inches long. It is first bent into a U-shape, as indicated by the full lines at *B*, in a bulldozer. After being bent in the bulldozer, the work is again put in the furnace and heated to the proper temperature. It is then removed from the furnace, and by means of bending dies held in the side shear of the forging machine, the ends are bent into the shape shown by the dotted lines *a*—partly over-lapping each other. After this operation, the piece is again placed in the furnace, heated to a welding temperature, and quickly removed and placed between the gripping dies shown to the left. The stationary gripping die carries two pins *D*, which serve as a means for supporting the work before the dies close on it. The welding and forming operation is accomplished by plunger *E*, which forms the work around the square impressions *F* in the dies, and at the same time
ends together, forming the spring band into one

interesting feature about this job is the fact that the excess amount of stock formed by the overlapping ends is distributed equally along the front side of the forging, making it 1/32 inch thicker than the original rectangular bar, and thereby increasing its strength at this point.

Dies and Tools for Making Extension Handle for Grate Shaking Lever

An interesting example of lap-welding is illustrated in Fig. 24, where the dies and tools used for forming an extension handle for a grate shaking lever are illustrated. This part, as shown at *A* and *B*, is made from two pieces—a rectangular bar of wrought-iron 2½ by ¾ inch, which has been sheared to an angular shape on one end—and a loop *B* formed from a piece of ⅝-inch rectangular bar iron bent into a U-shape in the dies illustrated to the left. The trimming of piece *A* and the bending of piece *B* is carried on at the same time with special shaped formers held to the top faces of the gripping dies. To do this,

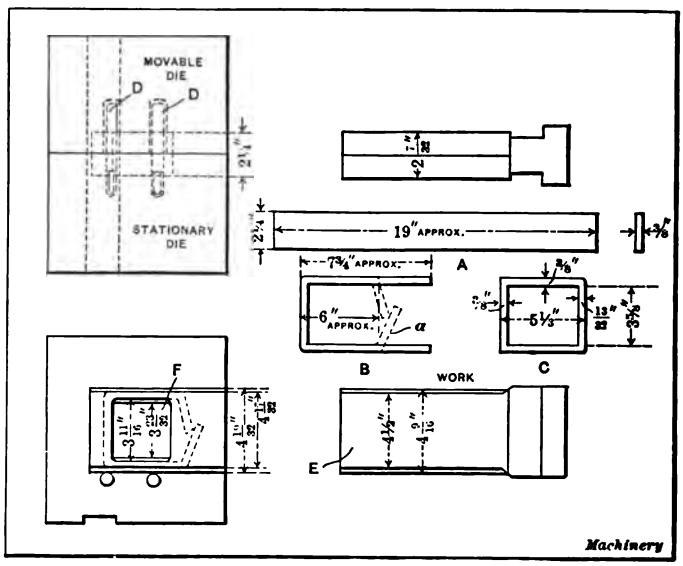

Fig. 23. Forging Machine Dies and Tools for making Locomotive Spring Bands

the operator first places a piece of rectangular stock of the required length in the impressions in the rear member *D* of the stationary gripping die; he then takes bar *A*, which has been previously cut to the required length, and places it in the impression at the front end of the gripping die. Upon operating the machine, the moving die advances and as it carries a plunger *E*, it forces bar *B* into the suitably shaped impression in the stationary gripping die. At the same time that this operation is being accomplished, the shearing plates *F* and *G* carried in the stationary and movable gripping dies, respectively, shear off the end of bar *A*.

The welding of these two parts is accomplished in the lower impres-

sion in the gripping dies which hold the pieces in position while punch *H* advances and upsets and welds the parts together. The two pieces are placed together and put in the furnace, heated to a welding temperature, then removed and given a tap, so that they will stick together. They are then put in the

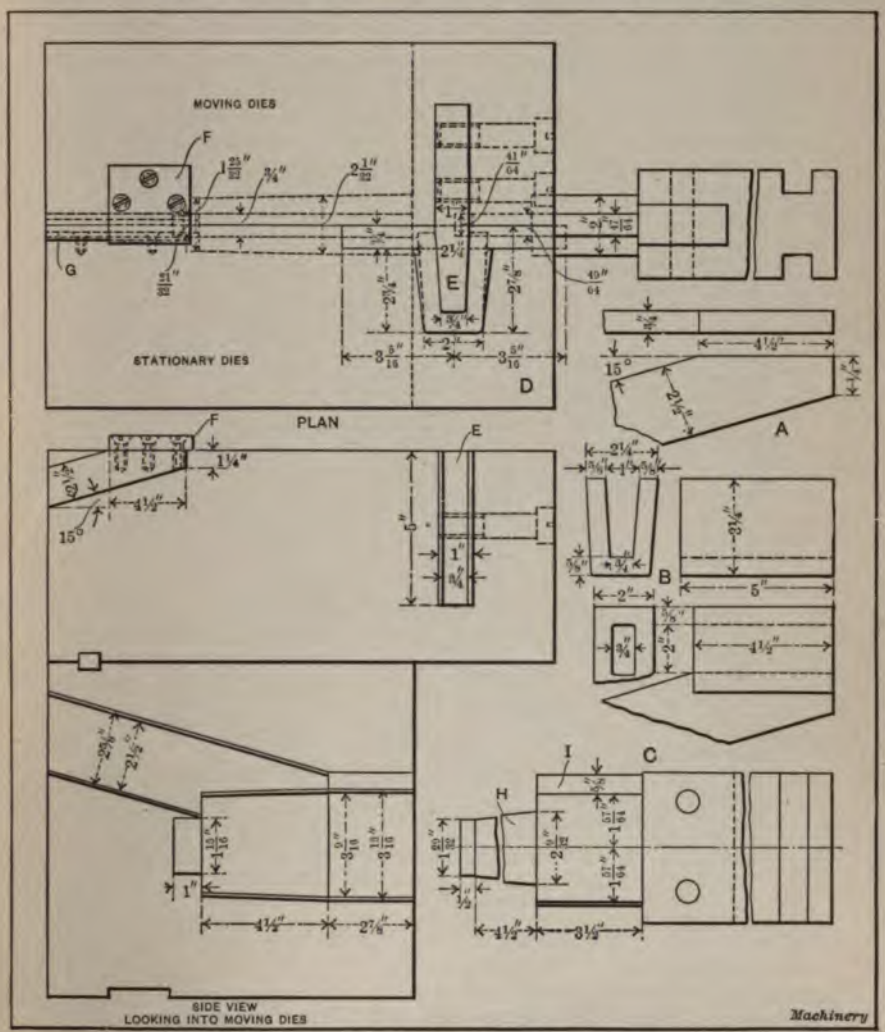

Fig. 24. Forging Machine Dies and Tools for making Extension Handles for Grate Shaking Levers

lower impression of the gripping dies and the machine operated. Then as the plunger *H* advances it enters the loop in part *B*, expanding it into the impressions in the gripping dies, and at the same t[illegible]he shoulder on the punch, carrying forward the excess [illegible]qually

throughout the forging, thus joining the two parts and producing a perfectly welded joint. Punch *H* is guided when in operation on the work by a tongue *I*, which slides in a corresponding groove in the gripping dies, and thus prevents any side movement of the punch.

Universal Type of Upsetting and Forging Machine

The miscellaneous welded and formed parts shown in Fig. 25 were forged in the Chicago shops of C. & N. W. Railway. The forging dies and tools shown in the following illustrations constitute a few of the many interesting examples to be found in the shop mentioned. All of the examples shown in Fig. 25 were produced on the 6-inch Ajax universal forging machine shown in Fig. 26.

The universal type of upsetting and forging machine shown in Fig.

Fig. 25. Miscellaneous Examples of Lap-welding and Forming Operations accomplished on a 6-inch Ajax Universal Forging Machine

26 has a much greater range of possibilities for producing machine made forgings than the regular upsetting and forging machines previously described. This machine has all the features common to the regular forging machine in combination with those of a powerful vertical press operated independently of the other part of the machine. The universal forging machine is designed especially for forming such forgings as require squeezing, punching or trimming operations either before or after upsetting. This often makes it possible to prepare and complete large upsets and difficult shaped forgings in one handling, and thus utilize the initial heat.

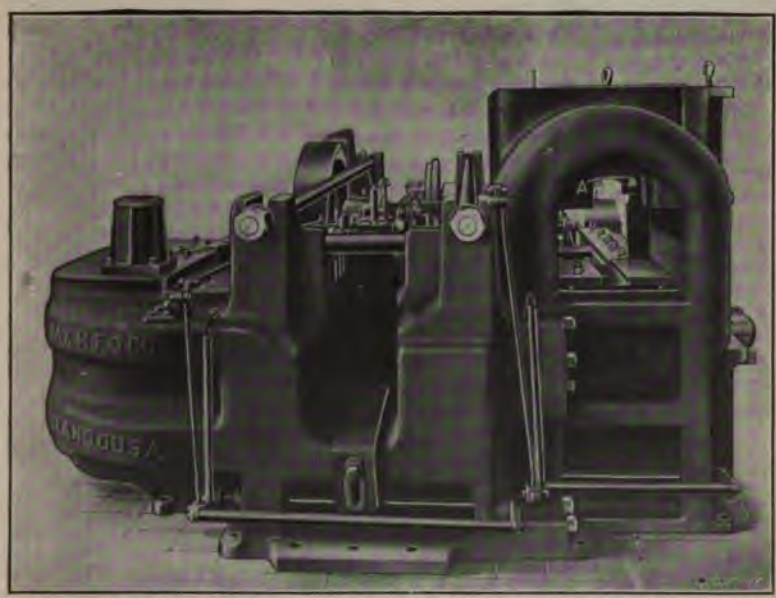

Fig. 26. Six-inch Ajax Universal Forging Machine used in the C. & N. W. Railway Shops for making the Forged Parts shown in Fig. 25

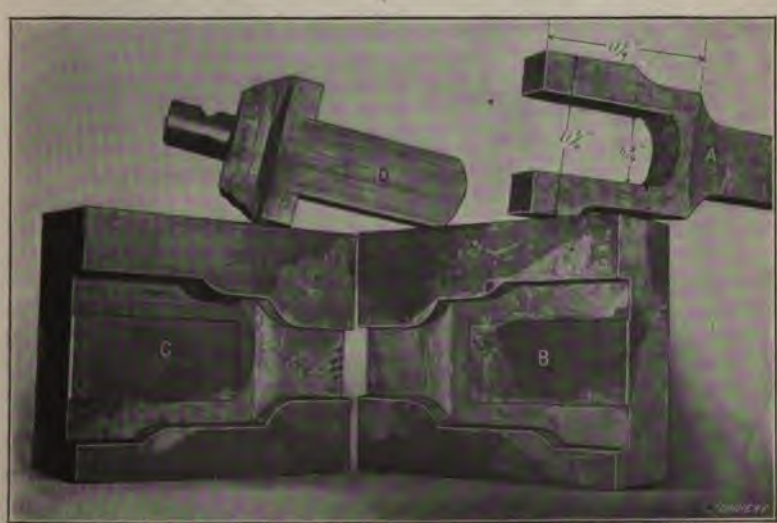

Fig. 27. Dies and Tools used in making Locomotive Main Rods in the 6-inch Ajax Universal Forging Machine

It consists mainly of a double-throw crankshaft from which are operated two header slides—one for the standard upsetting mechanism and the other for the vertical press. The upper die-holder *A* of the vertical press is operated by two heavy steel side links, the lower ends of which connect with eccentrics on an oscillating shaft. This die-holder is provided with means of adjustment so that the squeezing dies can be brought together or separated as requirements demand. The lower member of the dies used in this auxiliary part of the machine is held on the stationary die-holder *B*.

Dies and Tools for Making Spring Hangers

An interesting example of the utilization of scrap metal for making engine parts is the spring hanger *A*, Fig. 25. This part is made from old arch bars 1 by 4 by 5 inches, with the dies and tools shown in Fig. 28. Six blocks cut off from the arch bars are piled together and

Fig. 28. Dies and Tools for making Spring Hangers in a 6-inch Ajax Universal Forging Machine

riveted as shown at *A* in Fig. 29, the old holes in the arch bars serving as a means for riveting them together. This is done to hold the separate blocks in place while reaching a welding heat. After the parts have reached the proper temperature they are taken to the universal forging machine shown in Fig. 26, and placed between squeezing dies held in the vertical press. The machine is then operated, welding the pieces together and converting them into a solid block as shown at *B* in Fig. 29.

After the separate pieces have been welded and shaped, the solid block is again taken to the furnace and heated to a welding temperature. Then it is removed and placed between the opposing faces of the gripping dies *B* and *C*, Fig. 28, these being held in the forging machine shown in Fig. 26. The stationary gripping die *B* is provided with the shelf *D* on which the heated block is placed, this serving to hold it while the dies are coming together. As soon as the dies close on the

work, plunger *E* advances and displaces the stock in such a manner as to form the tail on the end of the forging *F* by simply forcing the center portion of the block back into the rear impressions in the gripping dies. This is accomplished in one heat, and when the piece is removed from the dies it is finished complete. Vent holes *G* are provided in the opposing faces of the dies to allow the excess metal to escape.

Another example of a spring hanger forging is shown at *B* in Fig. 25, the dies and tools used being shown in Fig. 30. The first operation in the forging of this spring hanger is to draw the 2-inch wrought-iron bar *A* down to the shape shown at *B*, Fig. 31, in a Bradley steam hammer. This piece, after being drawn down, is heated and placed in a

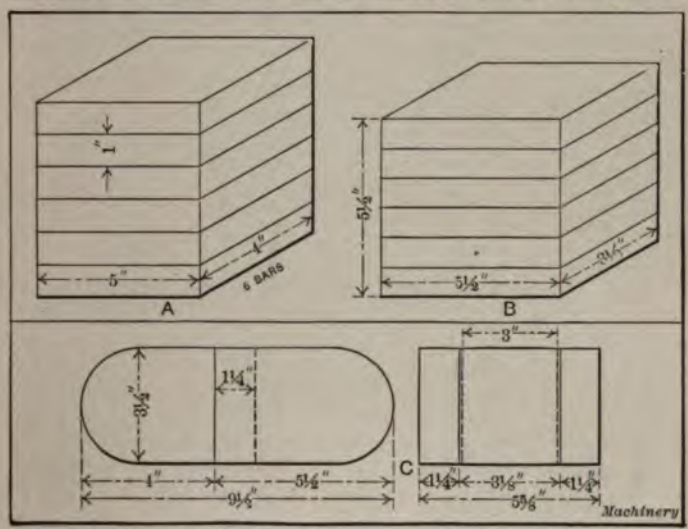

Fig. 29. Sequence of Operations on Spring Hanger shown at A in Fig. 25 and also in Fig. 28

bulldozer, where it is bent into a U-shape as shown at *C*, the heaviest part of the piece being located at the bent end. The one-inch hole is punched through the bent end at the same time that the work is being formed. The body or shank of the hanger is made from a 1 by 4-inch piece of round edge iron *D* which is swaged down on a 4-inch forging machine to 1¾ inch round for a length of about 7 inches on one end, as shown at *E*. The bar is then heated, placed in the forging machine and upset to 2 inches in diameter in order to completely form the reinforced portion on the flat part, and at the same time reduce the end to one inch in diameter. The reduction on the end of the bar is accomplished with the plunger held in the ram of the machine.

The loop *C* is now placed on the reduced end of the rod as shown at *G* an riveted cold, just enough to hold the two pieces together The work is then raised to a good welding he lower groove *A* (see Fig. 30) of the

dies held in the 6-inch forging machine shown in Fig. 26, where the work is formed by plunger *B* (Fig. 30). The reason for doing this work in a 6-inch forging machine is that the plunger travel necessary is 14 inches, and this would be impossible on a smaller machine than that having a 6-inch capacity. This 14-inch travel, of course, is after the dies have been closed on the work. After the two pieces are welded together as shown at *H* (Fig. 31) a block *a* of 2-inch square iron 3 inches long is placed in the U-end of the forging as shown at *I* and a welding heat taken. The work is then placed in the upper groove *C*, Fig. 30,

Fig. 30. Dies and Tools used in making Spring Hanger shown at B in Fig. 25—also illustrating Pin Welding Operation

of the dies and as the plunger *D* advances it upsets the forging to the proper shape around the embossed center portions *E*, the excess metal flowing up through the vent holes *F* provided in the gripping dies. The finished forging is shown at *J* in Fig. 31.

Still another type of spring hanger which is completed in the forging machine is shown at *C* in Fig. 25. This is made from a rectangular bar of wrought iron which is first lapped over and then welded, after which the eye end is formed to shape on the forging machine. The square hole is rough-formed by the vertical press of the universal forging machine shown in Fig. 26, and is then finished in the upper impression in the dies held in the horizontal part of the forging machine. No material is removed to form the square hole, the metal simply being expanded, increasing the width of the bar.

Dies and Tools for Making Fork End of Main Driver-Brake Pull Rod

The fork end of the main driver-brake pull rod shown at *D* in Fig. 25 is made from a 2¼-inch bar or round wrought iron which is first squeezed down flat on one end until the flattened end is 3 inches wide by 14 inches long. This operation is handled in the vertical head of the machine shown in Fig. 26. A piece of ½ by 3 by 14-inch wrought iron is laid on the flattened portion of the bar (both pieces, of course, being heated) so that they can be stuck together by the dies held in the vertical head of the universal forging machine, thus holding them while the welding heat is being taken. The next step in the forging of this fork is to increase the diameter of the rod from 2½ to 3 inches square. This operation is accomplished in the upper grooves *A* of the dies shown in Fig. 32, using the plunger *B* for upsetting. The 3-inch squared end is now split for about 9 inches of its length with suitable

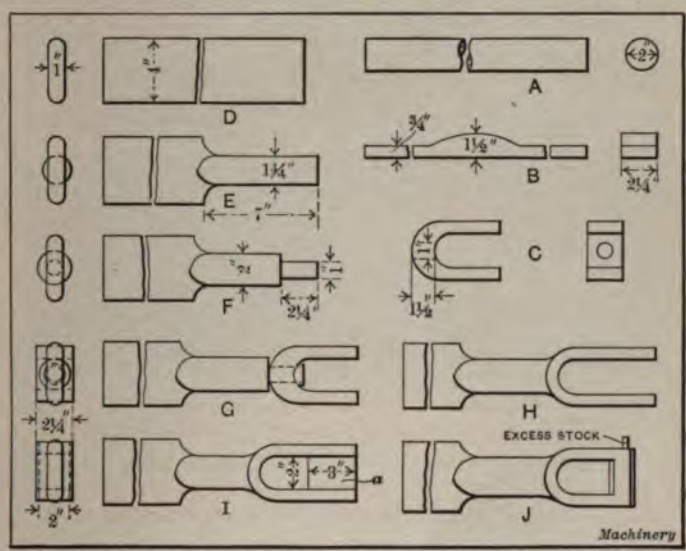

Fig. 31. Sequence of Operations performed on the Spring Hanger B shown in Figs. 25 and 30

tools held in the vertical head of the machine, and at the same time is opened up slightly. The piece is then taken to the furnace and heated, after which it is placed in the lower grooves *C* of the dies, and with one blow of plunger *D* is brought to the final shape shown at *E*.

Dies and Tools for Making Slot End of Main Driver-Brake Pull Rod

The slot end of the main driver-brake pull rod shown at *E* in Fig. 25 is made as shown in Fig. 33 from two pieces *a* of 1 by 2½-inch flat bar iron 27 inches long, one piece *b* of 3-inch square iron 3½ inches long, and one piece *c* of 2½-inch square iron 5 inches long. The two pieces *a* are clamped by a pair of tongs on the end where the block *c* is located and a welding heat is taken on the other end. The work is then

removed from the furnace by the tongs and quickly placed in the top groove of the dies. The machine is operated, and as the plunger, which has a punch on its front end, advances, it punches a hole in the work and displaces the stock, forming a boss on each side as indicated at *B*. The position of the tongs on the work is then reversed and the other end of the forging is heated, after which it is swaged to 2½ inches in diameter for a distance of 5 inches on this end to the shape shown at *C*. This operation is handled by the gripping dies which are provided with circular grooves located between the upper and lower impressions. The forging is again heated and placed in the

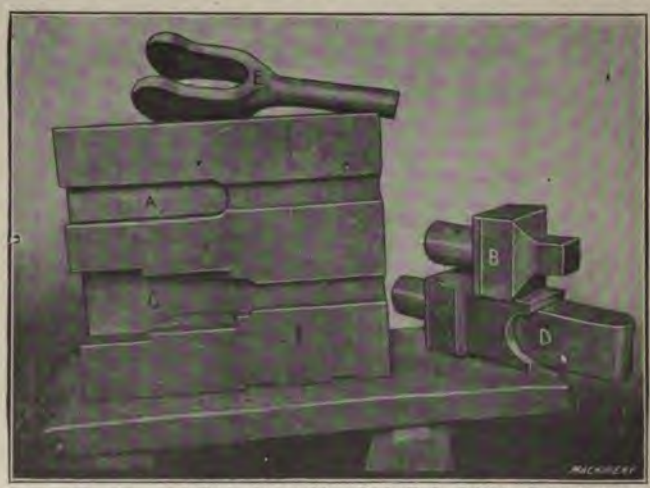

Fig. 32. Dies and Tools for making Fork End of Main Driver-brake Pull Rod shown at D in Fig. 25 in a Forging Machine

lower impressions of the dies, the round part entering the plunger. The machine is then operated, forming the forging to the shape shown at *D*.

Butt-welding Bottom Connecting-Rods for Freight Cars

Butt-welding is seldom done on forging machines, owing to the difficulty generally experienced in successfully making this type of weld. The bottom connecting-rods shown at *F* in Fig. 34, are, however, produced satisfactorily by butt-welding in the Collinwood Shops of the L. S. & M. S. Railway. The stock for the forked ends *A* is sheared off from a bar of 2½ by ¾-inch wrought iron and bent to a U-shape in the bulldozer. The center portion of this connecting-rod is made from 1¾-inch round wrought-iron bars which are also sheared to the required length before coming to the forging machine.

The U-shaped pieces *A* and bars *B* are now placed in a furnace where they are heated to a welding temperature. The operator then removes a rod and also a U-shaped piece and butts them together; he then places the pieces which are stuck together in the impressions in the gripping dies *C* and *D*, and operates the machine. Now as plunger *E*, which has a pointed end, advances, it forces [illegible] through the fork

into the round stock, thus intermingling the grain of the material and insuring a solid weld. To prevent scale from forming on the pieces to be welded, a small jet of compressed air is made to play on them just before and while the machine is operating.

After welding, the work is removed from the gripping dies and placed between suitably shaped forming dies held in the side shear.

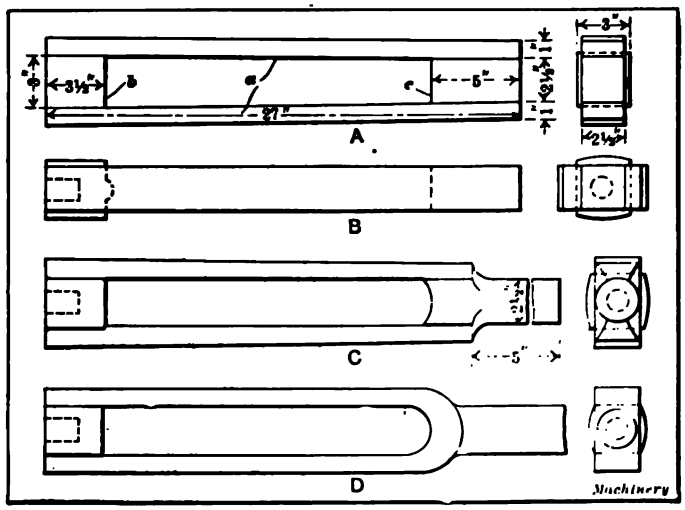

Fig. 33. Sequence of Operations performed on the Slot End of the Main Driver-brake Pull Rod shown at E in Fig. 25

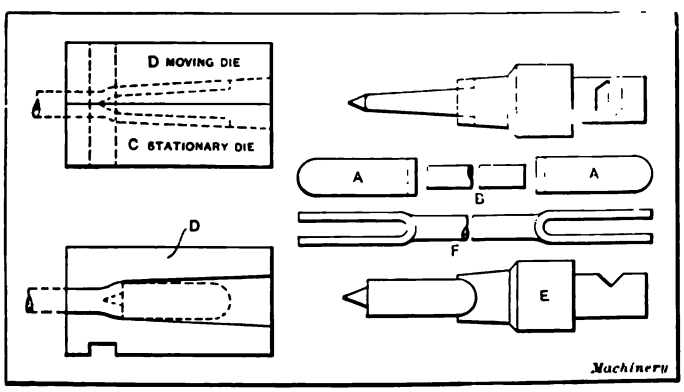

Fig. 34. Illustrations showing Sequence of Operations in the Butt-welding of Bottom Connecting-rods

The machine is then operated, forming the U-shaped end to the proper shape, after which the piece is thrown down in the sand to cool off. After all the rods have been completed in this manner, the other or straight end is placed in the furnace and the same procedure repeated. The con ottom connecting-rods are shown at *F*. To prove that

this type of weld was satisfactory, numerous tests were made to break it at the welded joints. This was not accomplished until the testing machine registered a pull of 74,000 pounds, which is equivalent to a tensile stress of approximately 30,000 pounds per square inch. As the tensile strength of wrought iron seldom exceeds 48,000 pounds per square inch, it will readily be seen that this type of weld would be satisfactory for the general run of forged work.

The Bulldozer as an Auxilliary to the Upsetting and Forging Machine

Considering the fact that so many parts completed on the forging machine can be handled successfully only when partially formed by the bulldozer it may not be out of place to include a short description of this type of machine. Fig. 35 shows the type of bending and punch-

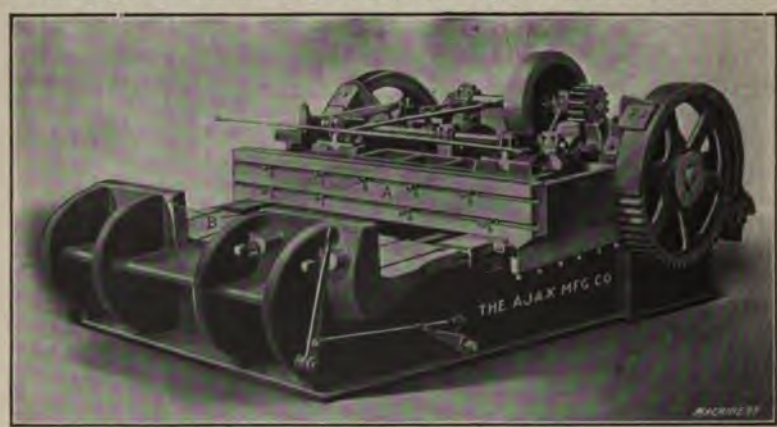

Fig. 35. Ajax No. 7 High-speed Bulldozer—an Adjunct to the Forging Machine

ing machine known as the bulldozer, which is used extensively as an auxiliary to the forging machine in the manufacture of many forgings.

The construction of this type of machine is simple, consisting primarily of a moving crosshead *A* which carries one member of the forming dies, the other member of the forming dies being held against the toes *B* of the machine. The operations are accomplished by the forward travel of the crosshead, the work as a general rule being completed in one travel of the head. Of course, while the machine is fairly simple in construction and operation, many types of interesting forming tools are used.

The forming tools for the bulldozer can generally be made cheaper and more conveniently from cast iron, especially when they are provided with hardened steel plates where any friction takes place—that is, those parts of the tool which actually do the forming or shaping should, as a general rule, be reinforced with hardened steel plates. This enables the tools to be renewed very cheaply, as the plates when worn out can be replaced by new blocks of steel. The roller type of tool which is carried and operated by the crosshead is the best saving material and power when it is possible to use this type. T

Fig. 36. Dies and Tools used in the Ajax 6-inch Universal Forging Machine for making Locomotive Side Rods in the C. & N. W. Railway Shops

ever, the type of tool to use depends largely on the shape to be formed and other requirements. In all cases where hot punching or cutting is done, high-speed self-hardening steel should be used for the working members of the tool.

Tools for Making Engine Main and Side Rods in the Forging Machine

The locomotive main rod shown at *A* in Fig. 27 is the largest piece of work ever handled in a forging machine in the Chicago shops of the C. & N. W. Railway. The main rod is first roughed out under a steam hammer and the end split before it is brought to the forging machine shown in Fig. 26. The roughing out of the slot and the finish-forming in the forging machine are done in one heat. In the forging machine the work is gripped by the dies *B* and *C*, and is upset and formed to shape by the plunger *D*.

Another good example of heavy forging done in the Ajax 6-inch universal forging machine is the locomotive side rod shown at *A* in Fig. 36. This side rod is made from square stock drawn down to the required size under the steam hammer, and is upset and formed on each end in the forging machine shown in Fig. 26. The gripping dies, only one of which is shown at *B* in Fig. 36, are used for forming the end *C* of the rod. It requires two operations to complete this end. The first operation is performed in the lower groove *D* of the dies and consists in rough-forming the slot with the plunger *E*. The work is then placed in the upper groove *F* and completely formed to shape by means of plunger *G*.

The other end *H* of the side rod is upset and formed to shape by another set of dies—only one of which is shown at *I*. The rod, which is heated to a welding temperature, is placed in the impressions in the gripping dies and is upset and formed to the required shape by means of the plunger *J*. These two examples of machine forging illustrate very well the adaptability of the forging machine to locomotive building.

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Locomotive Design, Part III.
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Locomotive Building. — Wheels; Axles; Driving Boxes.
Locomotive Building. — Cylinders and Frames.
Locomotive Building.—Valve Motion.
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THE INDUSTRIAL PRESS, Publishers of MACHINERY

140-148 LAFAYETTE STREET **NEW YORK CITY, U. S. A.**